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**California Department of Water Resources
Oroville Division, State Water Facilities
FERC Project No. 2100**

Operations Model Documentation

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Introduction

On January 28, 2002, the Plenary Group formed a Model Review Task Force to address concerns related to model development, analyses, and reporting for the Oroville Facilities Relicensing Process. The Model Review Task Force was directed to develop a general approach to model review that would ensure transparency and credibility in model use and instill confidence among the various collaborative participants that models used are appropriate for evaluating how changes in Oroville operational criteria affect conditions in areas considered as part of the relicensing of the Oroville facilities. On June xx, 2002, the Model Review Task Force submitted a set of protocols for assessing, documenting, and using models.

This report provides the documentation of the models being used for evaluating the operations of the Oroville Facilities, as well as other selected modeling tools that are being used to assess environmental and socio-economic impacts.

Summary of Models Being Reviewed

The following is a summary of the models that are documented in this report. More detailed information regarding each model is provided later in the report.

1. CALSIM II – Models the State Water Project and Central Valley Project using a monthly time step. It allows for assessment of water supply impacts as well as provides operational guidance for the other operations models.
2. Local Operation Model – Models the Oroville facilities operations at an hourly time step with a particular focus on hydropower operations.
3. Water Temperature Model – Models temperatures in the Oroville – Thermalito Complex and in the Feather River downstream from the Oroville Reservoir to the confluence with the Sacramento River as a single, integrated system.
4. Flow Stage Modeling – Used to develop flow stage relationships along the Feather River from Oroville Reservoir downstream to the confluence with the Sacramento River.
5. Geomorphic Modeling – Models sediment movement in the Feather River. The model will be used to provide input to analysis of scour and erosion within the river.
6. Terrestrial Habitat Modeling – Models bank and shallow water terrestrial habitats.
7. Physical Habitat Modeling – Simulation used in conjunction with the instream flow incremental methodology that combines hydraulic data with biological criteria to estimate available optimum habitat in a stream for particular species and life stages of fish.
8. Economic Impact Assessment Modeling System – A set of computer software and databases that provide for local level input and output models for estimating economic impacts associated with various recreational, tourism, and business activities in the community.

Model Integration

There are two model integration issues that must be addressed. The first deals with sharing data between models. The first three models identified above make up the operations modeling system. That is, they are used to simulate how the Oroville Facilities are operated under varying conditions and assumptions and they require that data be exchanged between models. The other models identified above are generally used to assess the effects of the resulting operations on specific resource areas, or they are used to develop important data for input to other models (such as the Flow Stage Model). Most of these impact models use the results of the operations models as input. In any case, output from one model that is used as input to another model must be converted to a usable form.

To ensure that models can “talk” to each other, a unified, operations modeling system is being developed. The system will allow for translation of data from one operations model to another and will allow for translation of operations simulation data for input to the other modeling tools. Implementation of the system requires development of tools to translate the output from some models and prepare input to subsequent models. The system will also require a database to store intermediate modeling results and to serve as the conduit to pass data between the models.

As critical as it is to share data between the operations models (and subsequent export of operations modeling data to the impact models) be resolved, it is also important to provide a feedback mechanism. This allows results from lower level operations models to influence the assumptions made for higher level operations models as well as providing a means for information developed from the impact models to feedback to the suite of operations models. To provide feedback within the suite of operations models the operations models will be used in a stepwise fashion, from higher level models to lower level models.

1. **Statewide Operation Modeling** – A series of scenarios will be simulated first using the CALSIM II model. The results from these simulations will provide the necessary guidance to lower level models for detailed simulation of proposed alternatives. Generally, the CALSIM II model will not be used to simulate every alternative, unless the proposed alternative has the potential for water supply impacts. In such cases, the proposed alternative will be simulated by selecting the appropriate CALSIM II benchmark simulation(s), and modifying the assumptions as required for the proposed alternative, and running the required simulations. The resulting simulation will then be evaluated and, if required, the assumptions modified and the simulation repeated until the final results are acceptable. These results are then available as input to the next level of operations simulation (if such simulation is necessary) or as input to other impact modeling analyses.
2. **Local Operation modeling** – If the proposed alternative has the potential for operational impacts that cannot be measured by CALSIM II then the Local Operation Model will be used. The simulation from Step 1 will be used to generate the

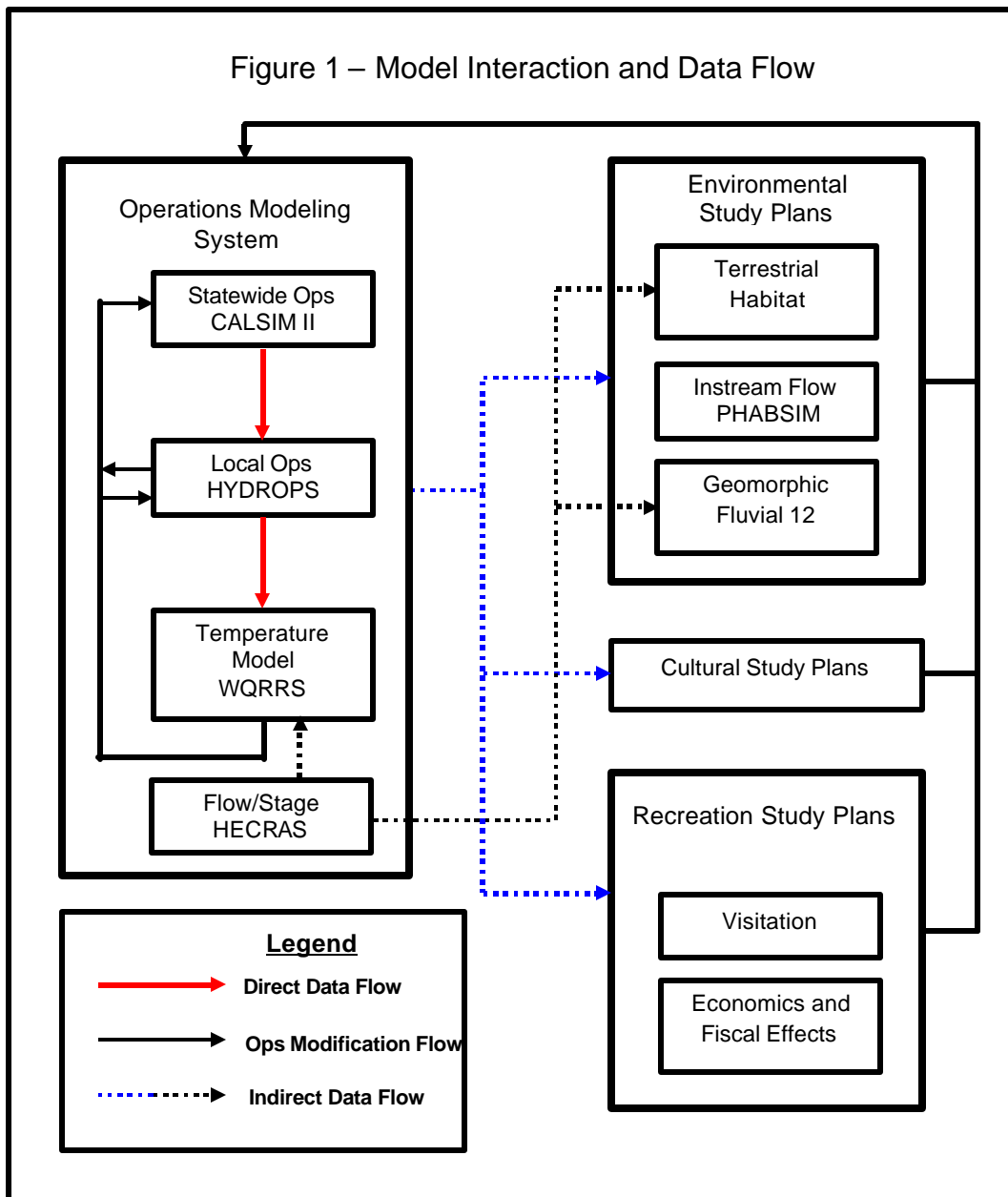
seasonal water-supply based operational constraints. These constraints, along with other assumptions modified as required for the proposed alternative, are used as input to the local operation model. The resulting simulation will then be evaluated and, if required, the assumptions modified and the local operation simulation repeated until the final results are acceptable.

The operational constraints noted above are treated as “soft” constraints; that is, the local operation model is allowed to deviate from them if necessary to achieve acceptable results. Furthermore, the local operation model may reveal instances when the assumptions used within, or operational decisions simulated by the statewide modeling are not acceptable. In these cases the process would go back to step one and repeat the statewide operation modeling with assumptions modified to reflect the new information from the local operations modeling.

3. Temperature modeling – Once the local operation modeling is completed the temperature model will be used to simulate the temperatures throughout the system using the operational data from the local operation simulation(s). The resulting simulations will then be evaluated to see if they are acceptable. If the simulated temperatures are not acceptable there are several possible courses of action. Below is an example of a series of actions that could be tested to achieve an acceptable simulation of temperature operations:
 - A. Modify the outlet shutter operation at Oroville Reservoir. - Oroville release temperature can be manipulated by changing the shutter configuration on the intake structure with NO other changes in operation allowed. In this case only the temperature model would need to be re-run to perform the next simulation for evaluation.
 - B. Modify the local power operations. Heat gain can occur through pumpback, generation peaking, or Thermalito Complex operations. By changing power operations and therefore the balance of water that flows through the Thermalito Complex and the Feather River low flow channel the temperatures in the Feather River can be manipulated. This type of evaluation would require that the local operation simulation be repeated with new assumptions, and the temperature simulation repeated with the new local operation results.
 - C. Modify the statewide operations. Changes to the seasonal operation at Oroville have the potential to affect the cold-water pool in the reservoir at different times of the year. This type of evaluation would require that the statewide operation simulation be repeated with new assumptions, and the local operation and temperature operations repeated with the new results.

Upon completion of the operations simulations, modeling data will be processed and provided to other models as needed. **Figure 1** is a flow chart of the model interactions during the simulation and analysis process. Once analyses are performed with the non-

operations, resource impact models, it may be necessary to rerun any or all of the operations models with new assumptions.



The core of the model integration is a central, modeling database that will be used to store all data that is to be passed between the operations models and/or required to produce outputs for analyses or non-operations models. Time series data from the operations modeling will be managed with the Data Storage System (DSS) developed by the US Army Corps of Engineers (USACOE) Hydraulic Engineering Center (HEC). This software was selected for several reasons:

- It provides an efficient method for handling large volumes of time series data.
- It is in the public domain, thus, it is available for anyone to use.
- It provides a programming interface that allows for custom tool development if needed.
- It can interface with productivity tools such as Microsoft Excel through another publicly available software.
- It is used to store the CALSIM II time series based input/output data.

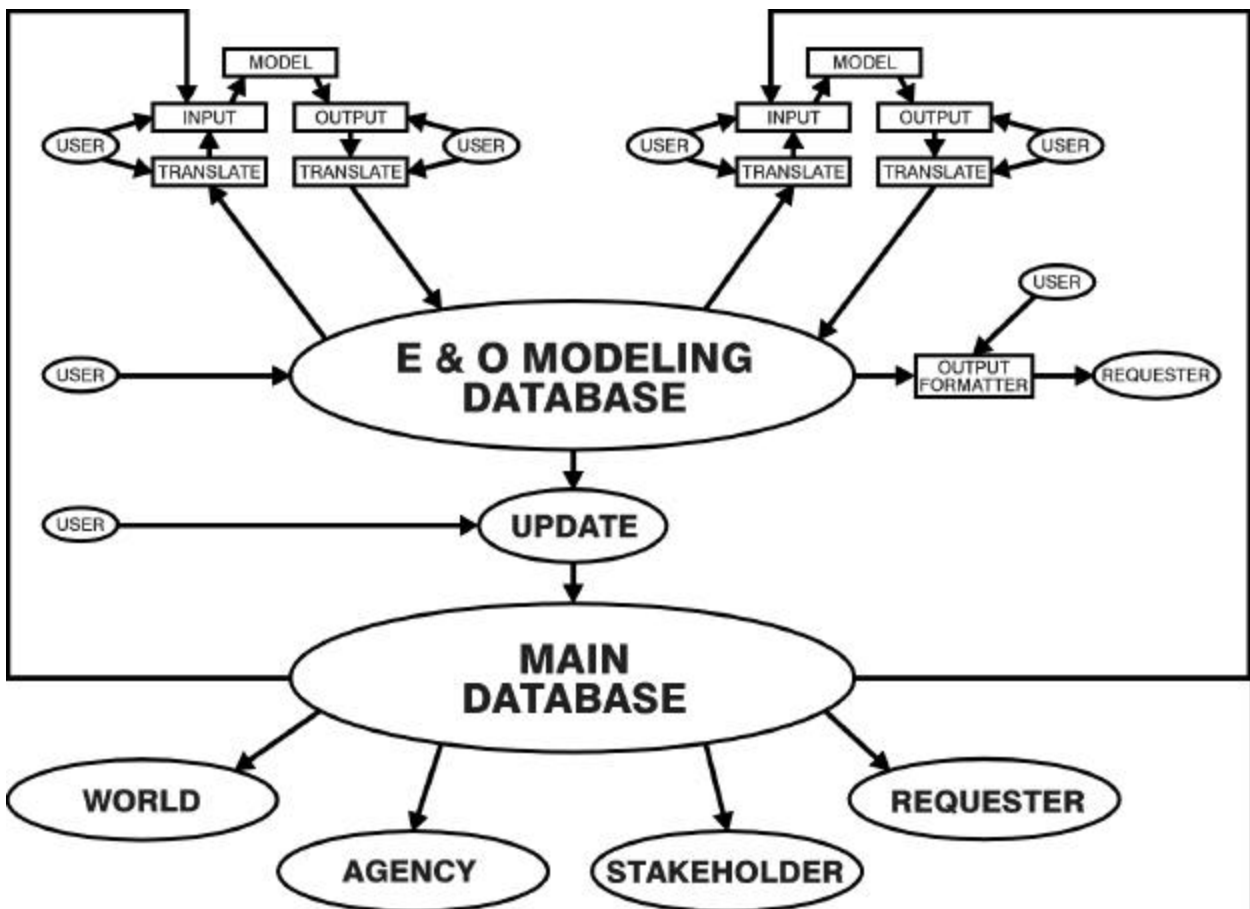
The individual operations models will not be modified to read or write data directly to or from the central DSS database. Instead, a set of tools are being developed that will transport data between the DSS database and models. In addition to linking the central database to the models, the tools will:

- Perform any required data manipulation such as converting monthly reservoir inflow data to daily reservoir inflow data.
- Allow the modeling team to review specific model results interactively. This is important because it allows modeling and operations staff to quickly assess model output and make necessary adjustments for subsequent simulations.
- Produce customized outputs for additional analyses.

The database will not contain finished simulation results. Instead, it will contain intermediate modeling data that may need review before being released for further analyses. In other words, model results for one scenario will likely consist of a series of interactive and iterative model runs to produce output that is acceptable. Therefore, when simulations for a scenario are completed and the modeling process is finished, the final results will be uploaded to a database that can be accessed by personnel involved in study plan analyses.

Figure 2 shows how data will be handled both within the proposed modeling system as well as the interactions with other modeling, analysis, or presentation processes.

Figure 2 – Database and Modeling Dataflow Schematic



Statewide Operation Model – CALSIM II

Description

CALSIM II is a monthly time-step simulation model of the combined California State Water Project (SWP) and the USBR Central Valley Project (CVP) systems and areas tributary to the Sacramento-San Joaquin Delta. This includes important non-project facilities on the east side of the Central Valley. CALSIM II is designed to be used for SWP/CVP planning purposes. For a given simulation the model adopts a static depiction of land use, water management facilities and their operational rules and constraints. The model sequentially applies this depiction to the hydrologic conditions encountered in California during the period from 1922 through 1994. In effect, the model attempts to simulate what the response of system, described in the simulation, would have been if it had been operated over the period of record.

Agricultural and urban target demands vary according to variations in precipitation (i.e. all SWP demands and CVP north-of-Delta demands) or are fixed at contract entitlement levels (i.e. CVP south-of-Delta demands). Elements of a depiction of the system can be adjusted from one simulation to the next in order to explore the implications of land use, infrastructure, and regulatory changes in the system.

CALSIM II is most useful when it is used to compare the results of one simulation against another in a way that isolates the impact of specific elements of the system depiction. It is usual practice to compare simulation results to benchmark simulations. Several benchmark simulations are being developed that may be adopted for various water planning efforts in California. For example, one benchmark simulation is based upon a future level of water development within the State; another assumes the current level of water development.

Regardless of the system depiction adopted for a simulation, the model employs a specific set of priorities in making water allocations for the CVP and SWP. The model will first meet environmental and in-basin requirements and second meet project contract and export delivery targets.

Usage

As part of modeling carried out in support of Oroville Facilities Relicensing process, CALSIM II will be used for two basic purposes:

1. Provide input regarding the operation of the Oroville Facilities that will support detailed modeling and analysis of conditions in Oroville Reservoir, within the Thermalito Forebay/Afterbay complex, and at an appropriate distance downstream in the Feather River.
2. Allow identification of potential system-wide impacts that could arise from this detailed modeling and analysis as a result of specific facility or operational

changes associated with meeting relevant management objectives in Oroville Reservoir, within the Thermalito Forebay/Afterbay complex, and at an appropriate distance downstream in the Feather River. This could include impacts on SWP water supply and power generation, environmental requirements, or impacts to CVP operations.

Since the model is capable of emulating system-wide operations of the SWP and CVP, it could facilitate analysis of appropriate system level measures that that may be considered as part of a cumulative impact assessment.

Limitations

CALSIM II is a planning tool designed for analysis of the long-term impacts of facility or operational changes in the system. It has limited usefulness in the analysis of specific year impacts resulting from short term trends or operational changes. Because it uses a constant level of development, it cannot be used for direct analysis of changes over time in a single simulation.

CALSIM II requires the analyst using the model to have extensive knowledge of the CVP/SWP systems in order to be used properly.

CALSIM II employs a monthly time step, which limits its ability to describe:

- A. Operational decisions or inputs at intervals shorter than a month, without implementing appropriate assumptions or simplifications.
- B. Event specific flood control scenarios (only seasonal flood control criteria such as flood control reservoir reservation can be modeled).
- C. Detailed hydropower analysis related to total capacity or on-off peak power generation (only gross energy production potential can be evaluated).

CALSIM II uses inflows to major reservoirs and local accretions and depletions that were developed by modifying the historic hydrology to account for the impact of land use change on runoff and the effects of storage regulation and stream diversions that are upstream of the areas simulated in the model. This is a complicated process that invokes multiple assumptions and that requires many months to complete. As such, making changes to the underlying hydrology evaluating the impact of these changes is difficult to accomplish in a reasonable timeframe.

Assumptions

CALSIM II was developed so as to facilitate the analysis of any set of desired assumptions and the comparison of the impacts of these assumptions to a benchmark. There are very few assumptions about the system in CALSIM II that are not under direct user control. For example, the user can produce a depiction of the system with virtually any type of facility or operational assumptions by adjusting the parameters, operational logic and weights used by the model. However, a relatively small set of processes in

the system using a complicated and extensive set of logic would be difficult and time consuming to change. For example the SWP delivery decision process that sets the SWP delivery each year is a sequence of computations and procedures that follow a set logic. While changing the parameters used in the process is very easy, changing the underlying logic itself is more difficult, but not impossible. Some examples of processes which rely upon logic internal to CALSIM II include:

- Delivery decision process
- San Luis Reservoir Operation
- Environmental Water Account and Central Valley Project Improvement Act section 3406 b(2) implementation

Inputs that shape the assumptions of a particular simulation consist of special program code (called WRESL), data files for numeric inputs, and parameters for specific rules.

Inputs

CALSIM II inputs fall into several major categories:

Natural System	- rivers, connectivity
Facilities	- reservoirs, canals, pumps
Hydrology	- inflows, in basin accretions and depletions, evaporation
Operation rules	- reservoir rule curves, exports, delivery allocation logic, Coordinated Operations Agreement, contractual requirements, and priorities (weights)
Regulatory Req.	- minimum flows, water quality, export limits, operational limits, and flood control limits

Outputs

CALSIM II outputs fall into the following major categories:

Reservoir operations
Flows throughout the system
Deliveries

Appraisal

CALSIM II cannot be calibrated in the traditional sense of the term since the model does not mimic any real-time data. The conditions in the model are NOT historic; the modeling conditions represent a planning level analysis with varied precipitation. The model is currently undergoing a rigorous review process with CVP/SWP operations and modeling experts from DWR, U.S. Bureau of Reclamation and consultants. This process will yield a version of the model and benchmark simulations that are acceptable to both Reclamation and DWR that can be used as a starting point for Oroville Facilities Relicensing process.

Local Operation Model – HYDROPS

Description

HYDROPS was developed by Powel Technology, Inc. (Powel; formerly, Charles Howard and Associates, Inc.) HYDROPS has been used by power utilities in the United States and Canada for operation, planning and relicensing purposes.

HYDROPS has both long-term and short-term study models. The long-term model has one-year time horizon with weekly time steps, and the short-term model runs for one week at hourly time steps. For simulating detailed, short-time step operations of the Oroville facilities, only the short-term model will be needed.

Usage

HYDROPS will be used to simulate hourly operations of the Oroville facilities using a weekly modeling horizon. The weekly timeframe is used since power production optimization is done over the same period.

Operational boundary conditions will be provided from the CALSIM II statewide operation modeling; these boundary conditions will be imposed as targets on the local operations model. HYDROPS will then optimize Oroville facilities hydropower operations while striving to meet the many operational targets imposed on it. In addition to the boundary targets provided by CALSIM II, the model will have to consider localized facility constraints, targets, as well as operation requirements that could not be captured accurately in the monthly time-step model.

Model output will be used to provide information on the Oroville facilities hydropower operations within the other operational limit assumptions, and within the seasonal water supply operation boundaries from the statewide modeling. Potential changes in the operational policy, requirements or facilities and any associated impacts will be evaluated. The optimization function of the selected local operation model is essential to adequately model the hydropower operations.

As with CALSIM II, HYDROPS will be used as a planning model; that is, each scenario that is simulated will be compared to a base condition for subsequent analyses. It will not be used for flood control or real-time operation decisions based on hourly flow predictions for the entire period of record. The model could be used to route specific flood events through the Oroville facilities, but such use is not contemplated for the relicensing process.

Limitations

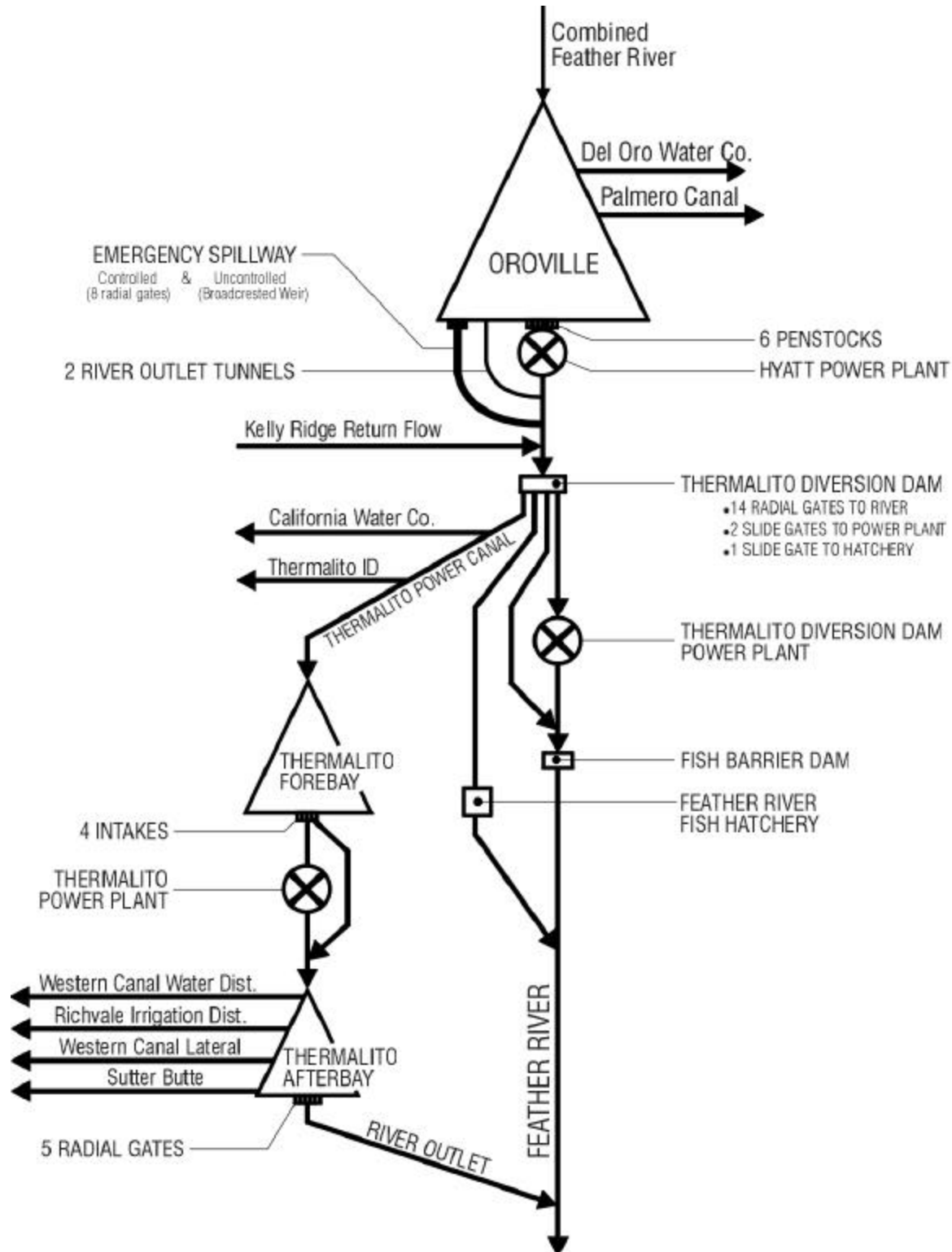
Local operation modeling will be based on the CALSIM II simulation results and thus results are subject to the accuracy of the CALSIM II simulations. The reasonableness of the local operations modeling will be evaluated during the simulation process.

The local operation model will use a synthetic hydrologic flow sequence which contains the same volume of flows as CALSIM II on a monthly basis. The monthly hydrology used as input to CALSIM II will be disaggregated into daily or hourly data using a set of typical year monthly flow patterns developed from historical hydrology. The resulting hydrology will not reproduce historical flood events.

Assumptions

HYDROPS will simulate the Oroville facilities and the Feather River to a point just downstream of the Thermalito Afterbay return to the Feather River. Figure 3 is a schematic of the Oroville facilities features that are to be modeled.

Figure 3 – Local Operation Model Schematic



Inputs

HYDROPS inputs fall into several major categories:

Natural System	- rivers, connectivity
Facilities	- reservoirs, canals, pumps, generators
Hydrology	- inflows, evaporation, diversions
Operation rules	- reservoir rule curves, contractual requirements, and priorities (weights)
Regulatory Req.	- in-stream minimum flows, in-stream water quality requirements (these must be estimated as flow constraints for simulation in the local operations model process), operational limits, and flood control limits

Outputs

HYDROPS outputs fall into the following major categories:

Oroville, Thermalito Forebay and Thermalito Afterbay storages
Flows throughout the system
Diversions
Power generation
Pump-back power requirements

Appraisal

While the simulations produced by the local operations model can be verified using recent historic data, the benchmark and alternative scenario simulations are dependant on the CALSIM II model to provide operational boundaries. As such the results of the simulations are subject to the same limitations as results of the CALSIM II models.

When used in a comparative mode as envisioned in this process this model will provide results compatible with the needs of the relicensing process.

Temperature Model – WQRRS

Description

WQRRS was developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center. The software has been widely used and is in the public domain, so it is readily available. WQRRS is being used to integrate modeling components to simulate temperatures of Oroville Reservoir, the Thermalito Forebay/Afterbay complex, and the Feather River from the reservoir downstream to the confluence with the Sacramento River. The integrated model will divide the Feather River below Oroville into segments as control volumes for heat budget calculations. These control volumes will be located at all compliance locations for critical habitats for fish and fish food organisms.

The integrated model will provide continuous temperature simulation of temperatures for all control volumes of the Oroville facilities. The time step of simulation can be hourly or daily depending on the need of biological considerations.

Usage

The temperature model will be use to simulate the temperatures throughout the system given a set of operational parameters such as storages, flows, releases, pump-back and diversions from the local operation model.

Limitations

The temperature model will not automatically re-operate the system to meet temperature targets; it will simply simulate the temperature from a given set of operational parameters. Simulation of the Oroville Facilities re-operation will occur through the step-wise modeling process described earlier in this document.

Assumptions

WQRRS emulates heat transfer processes by breaking the system being modeled into specific areas or control volumes. For each time step of computation, every control volume will have an estimate of water inflow (flow from an upstream boundary or control volume), outflow (flow to a downstream boundary or control volume), heat gain due to solar energy at the surface of the control volume, and heat loss due to evaporation.

Inputs

Temperature model inputs fall into several major categories:

Meteorological	- temperature, solar radiation, cloud cover, wind
Natural System	- rivers, connectivity
Facilities	- reservoirs, canals, river channel pumps

Hydrology	- inflow (flow and temperature) in basin accretions and depletions, evaporation
Operation data	- reservoir storages, reservoir releases, pumpback, flows throughout the system

Outputs

The integrated model will output the temperature profiles of the Oroville reservoir, which can be used to calculate the volume of cold water in the reservoir. The model will also output the reservoir surface elevations and temperatures of reservoir releases.

The integrated model will output temperatures of various control volumes and diversion flows for the Oroville facilities.

Appraisal

The accuracy of the model is measured by the discrepancy between the predicted values and observed values. This discrepancy actually represents the errors of both data and model. However, the discrepancy is commonly attributed to the model error. The degree of accuracy is unknown at this time. Past experience indicates that the error can be within one degree Celsius.